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International Journal of Industrial Ergonomics 36 (2006) 239–246

International Journal of INDUSTRIAL ERGONOMICS

www.elsevier.com/locate/ergon

Effect of knife sharpness on upper limb biomechanical stresses—a laboratory study

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Received 14 April 2005; received in revised form 4 November 2005; accepted 21 November 2005

Abstract

The aim of this laboratory study was to observe the effect of deteriorating knife sharpness on upper limb biomechanical stresses. Ten professional deboners were asked to perform the same carving task with both very sharp and very dull knives (i.e. under very good and very bad sharpness conditions). The knife sharpness characteristic was quantified using a cutting force measuring system. Surface electromyograms (EMGs) were recorded for the flexor digitorum superficialis, extensor digitorum communis (EDC), biceps brachii (BB), triceps brachii (TB), anterior part of the deltoid and upper part of the trapezius muscles. Wrist and elbow flexion–extension and wrist abduction–adduction angles were also recorded.

The results for the considered task showed that better blade sharpness leads to significantly lower EMGs for the flexor digitorum superficialis, BB, TB, anterior deltoid (AD), upper trapezius muscles and, to lower wrist radial deviation. No significant difference was observed for the EDC muscle or for wrist and elbow flexion–extension angles in relation to knife blade sharpness. The electromyographic activity of the EDC muscle remained very high, even when knife sharpness was excellent.

This study highlights the importance of training operators in knife honing/sharpening to ensure they have knives that cut easily. However, high activity of the EDC muscle demands further investigation in the field. Should this level of stress be confirmed, other prevention actions (knife design, organization-based through shift rotation or inclusion of micro-breaks, etc.) should be considered to reduce the risk of certain MSDs appearing, such as lateral epicondylitis.

Relevance to industry

This paper describes how the use of a badly sharpened knife can increase upper limb biomechanical stresses. Knife-sharpening training programs should be considered, along with other prevention actions, to reduce the biomechanical stresses sustained by meat industry workers.

Keywords: Meat industry; Knife sharpness; Upper limb; Electromyogram; Posture

1. Introduction

It is well known that working conditions are generally difficult in the meat processing industries. All recent statistical and epidemiological studies reveal a very marked prevalence of upper limb musculoskeletal disorders (MSDs) in the meat industry (Loppinet and Aptel, 1997). In France, latest known data show that, in 2002, 21% of recognized MSDs appeared in the food industry (CNAMTS, 2004). This fact confirms that there is a real occupational health problem in these industries and there are consequently strong MSD prevention issues at stake in the meat-processing sector.

Whilst growth in MSDs in the meat industry requires no further proof, their determinants remain, on the other hand, little known and are situated at different levels. Thus, Silvin (2000) refers to factors involving work organization (work rate, no shift rotation, time constraints), task performed (cycle time, repetitiveness, monotony, cognitive stress), wearing of gloves, work station, environment (cold,

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doi:10.1016/j.ergon.2005.11.007

humidity, noise pollution) and knife condition (design, honing, sharpening). The knife currently continues to be the emblematic tool of meat processing companies. Meat carving operations have indeed not yet been mechanized because of the highly variable nature of biological products. Scientific studies aimed at quantifying biomechanical stresses, to which meat carving operators are subjected at the work station, report high levels of force and movement repetitiveness, thereby confirming a high risk of MSD appearance (Christensen and Larsen, 1995; Marklin and Monroe, 1998; Silvin, 2000; Claudon, 2001; Bao et al., 2001; Juul-Kristensen et al., 2002). Training programs aimed at improving knife sharpness by suitable sharpening[1] and honing[2] are currently offered, especially France[3] and Quebec,[4] with a view to reducing biomechanical stresses sustained by carving operators.

A limited number of studies have been conducted on the relationship between sharpness improvement and its associated effects on biomechanical stresses. Bishu et al. (1996) first conducted a laboratory study about cutting forces required to cut Bologna round chub steak with sharp and dull knives. Significantly higher cutting forces were reported with a dull knife, but no significant effect was reported in relation to gripping force, which was measured using thin pressure sensors attached to the palm of the hand. Silvin (2000) attempted subsequently to examine the effect of deteriorated knife sharpness on flexor digitorum superficialis muscular stresses. Results of this study did not reveal significantly higher exertion of this muscle. However, it should be stated that operators evaluated subjectively the knife sharpness in this study. Operator sensitivity to knife sharpness is highly variable and experience, in particular, contributes greatly to operator feeling. More recently, McGorry (2001) developed a dynamometric knife, allowing measurement of the hand gripping force exerted by the operator on the knife handle and the couple applied to its blade. Using this instrument, it has been possible to observe significant increase in both hand gripping force and couple applied to a blade of reduced sharpness (McGorry et al., 2003; Dempsey and McGorry, 2004; McGorry et al., 2005). In this study, a knife sharpness tester measured the force required to cut a mesh material ensuring relative measurement for comparison of blade sharpness.

Past studies focused only on biomechanical stresses of the hand/forearm complex and none have attempted to investigate the whole upper limb. The aim of the present study was therefore to observe the consequences of knife sharpness deterioration (measured using a system specially designed for the study) on muscular exertions of the forearm, arm and shoulder muscles and on wrist deviations within the scope of a laboratory-based carving task.

2. Method

2.1. Subjects

This laboratory study was conducted on 10 right-handed professional deboners. Subjects had been previously informed of the experimentation content and aims, which had been authorized by the French Department of Health after acceptance by the consultative committee for the protection of biomedical research personnel. All subjects were in good health and none were suffering from upper limb musculoskeletal diseases. Participants' average age and average experience (standard deviations) were 43.2 (8.5) years and 22.5 (12.4) years, respectively. Their average heights and weights (standard deviations) were 1.73 (0.06) m and 79.8 (15.6) kg, respectively.

2.2. Task

Subjects were asked to perform a carving operation with knives, whose sharpness had been previously quantified using a cutting force measuring system (see a description). Subjects stood in front of an adjustable height table, on which sheets of foam rubber, similar those used on the cutting force measuring system, were positioned. Table height was adjusted such that the subject's elbow angle was 90° at the start of the carving action. Knives were held with a dagger handgrip as illustrated in Fig. 1.

A carving sequence involved cutting five foam rubber slices at a frequency of one slice every 3 s. Each subject was put through a preliminary learning phase to familiarize himself with the required carving frequency. The

Fig. 1. Foam rubber slice carving action using a knife held with a dagger handgrip.

[1]Passing the knife through a grinding- or rotary abrasive belt-type machine.

[2]Operation involving maintenance of the extreme part of the cutting edge, invisible to the eye, by passing repeatedly the knife over a honing steel or "cross-rods" system.

[3]The branch-specific participative approach applied to the meat industry by the CNAM, INRS and MSA.

[4]The development of a knife-honing training program, University of Quebec at Montreal (UQAM).

experiment entailed asking each subject to perform, in succession and in random order, a carving sequence using a knife that cut well and a knife that cut badly. The two successive carving sequences were repeated three times by each subject. The cutting force exerted on each knife was measured at the end of the experiment to ensure that it had not changed during successive carving sequences.

2.3. Cutting force measuring system

The relevant literature proposes several systems that are mainly distinguished by the type of magnitude measured. This can be effectively a force (Bishu et al., 1996; McGorry et al., 2003), a surface area corresponding to a blade imprint in gelatinous material (Szabo et al., 2001) or a thickness of paper cut by the blade (EN ISO 8442-5, 2002). After analysing the real action of a deboner holding his knife with a dagger handgrip (Fig. 2a), this study allowed us to develop a system for measuring the force exerted on a knife blade (Fig. 2b).

The cutting force measurement system is shown in the Fig. 3a. The knife is fixed to a knife holder made up of three parts (Fig. 3b). A first part (1), which is driven in translation (according the direction of the white arrow on the Fig. 3a). The second parts (2), which can swivel in angular motion, allows blade/sample angle to be modified. The third (3) part connected to the second by three sensors, allows measurement of tangential (Ft) and normal (Fn) forces exerted on the knife. Finally, a wire-based displacement sensor measures knife holder advance. Signals emitted by these different sensors are recorded for subsequent processing to determine the cutting force value with respect to knife displacement in the sample ($\mathrm{Fc} = \sqrt{\mathrm{Fn}^2 + \mathrm{Ft}^2}$) (Fig. 2b).

The variability of the mechanical characteristics of meat, which depend on the animal, its age, the muscle and its maturation, the temperature of the meat, etc. meant that it was inconceivable to use meat for quantifying sharpness. Special, 3-cm thick, homogenous foam rubber was therefore used (Fig. 3). The shear strength of this foam rubber is close to the average shear strength of meat, which is approximately 8 DaN/cm^2 (Kopp and Bonnet, 1982).

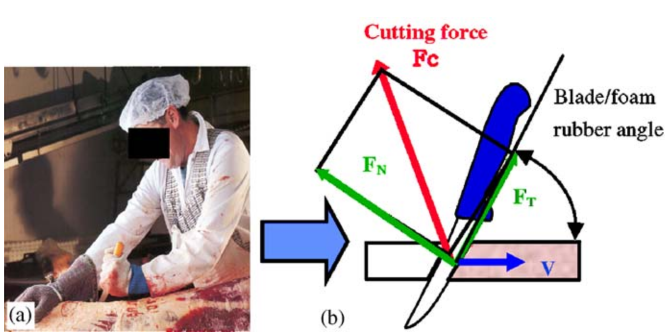

Fig. 2. (a) Real deboner action; (b) Forces measured using system.

The cutting force measuring system also allowed us to quantify "cutting edge retention", which represents the capacity for a cutting tool to resist to the wear. This characteristic was evaluated by measuring the change in cutting force after rubbing the blade against a brass cylinder at constant pressure (cf. Fig. 3a). This method made it possible to repeat this rubbing action several times to obtain quickly a high degree of wear. The complete description of the cutting force system measurement is described in Marsot et al. (2004).

For the present study, 10 boning knives with 17 cm blade length (manufactured by French cutler DASSAUD Fils SA) were sharpened to give a cutting force of between 25 and 30 N ($m = 28.5$ N; SD $= 2.6$), corresponding to "good cutting", and 10 knives were dulled, by abrading the blade against the brass cylinder, to give a cutting force of between 75 and 80 N ($m = 78.8$ N; SD $= 4.2$), corresponding to "bad cutting". The cutting force ratio between the two cutting conditions considered was therefore approximately 2.8.

The choice of the above cutting force values is explained in the first part of the discussion section below.

2.4. Electromyography

The surface electromyogram (EMG) was recorded for the right flexor digitorum superficialis (FDS), extensor digitorum communis (EDC), biceps brachii (BB), triceps brachii (TB), anterior deltoid (AD) and upper trapezius (UT) muscles. After suitable skin preparation, the EMG was recorded using surface (Blue Sensor®) electrodes placed according to recommendations given by Zipp (1982) and Mathiassen et al. (1995). Inter-electrode distance and impedance were 2 cm and less than 5 kΩ, respectively. The EMG was filtered, amplified, digitized at a frequency of 1000 Hz, rectified and then integrated per 50 ms period. To standardize the EMG of the first 4 muscles referred to above, the subjects were seated with the right shoulder abducted to approximately 20° and the right elbow flexed to 90°. Initially, subjects were asked to perform three maximum voluntary contractions (MVC) when gripping a handle fitted with an Entran® force sensor. Each MVC was separated by a three-minute rest period to avoid appearance of muscular fatigue. Only the highest MVC was retained as a reference value. This procedure allowed a reference value to be simultaneously retained for the flexor digitorum superficialis and EDC muscles. The subjects were then asked to perform successively three intentional maximum contractions when flexing the elbow, then three intentional maximum contractions when extending the elbow, to obtain a reference value for the BB and TB muscles, respectively. As in the case of the flexor digitorum supercialis and EDC muscles, only the highest of the three MVCs was retained as a reference value. Each MVC was also separated by a three-minute period to avoid appearance of muscular fatigue.

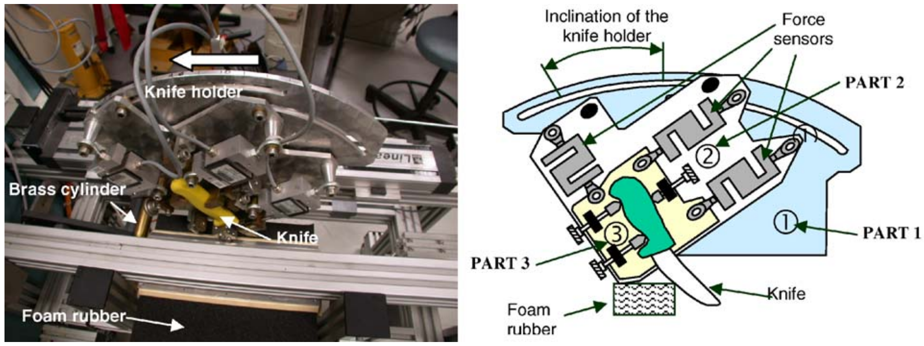

Fig. 3. Cutting force measuring system: (a) photo of the system: (b) details of the knife holder.

With regard to the AD and UT muscles, the EMG signal standardization procedure involved a reference voluntary contraction (RVC), during which the subject was standing, arms stretched in abduction to 90°, palm of the hand facing down (Mathiassen et al., 1995).

Values recorded during experimentation were then expressed as a percentage of the values retained according to standardization procedures.

A mean maximum value (Max) was calculated for the 20 highest successive points for each foam rubber slice carving operation. Furthermore, an amplitude probability distribution function (APDF) (static level: $p0.1$; median level: $p0.5$ and peak level: $p0.9$) was derived for the whole carving sequence (carving of five slices) period to compare stress levels in the studied muscular groups with the limiting values suggested by Jonsson (1982). Thus, eight values were obtained for each carving sequence: five values corresponding to mean maximum values calculated for the 20 highest successive points of each slice carving operation and three $p0.1$, $p0.5$ and $p0.9$ values from the APDF analysis, calculated for the whole carving sequence period.

For each considered muscle, initial general linear model (GLM)-based statistical analysis was performed using maximum values as dependent variables and both subjects (1, …, 10) and sharpness (good, bad) as independent qualitative variables. A second GLM-based analysis was then performed on the $p0.1$, $p0.5$ and $p0.9$ values from the APDF analysis, using the same independent factors as those defined for the initial analysis. The "subject" factor was declared as random variable in both these analyses.

2.5. Goniometry

Two Penny & Giles® goniometers were fitted to the right wrist and right elbow of each subject. These goniometers, fixed to the body using double-sided adhesive tape, allowed both wrist flexion–extension and abduction–adduction and elbow flexion–extension angle to be measured. Each goniometer was positioned according to its manufacturer's recommendations. For each carved foam rubber slice, a mean value for the same 20 points as those used when calculating the EMG signal maximum values was calculated for each of the three measured angular deviations. A GLM-based statistical analysis was also performed for each of the three measured angular deviations using mean angular values, calculated according to the method described below, as dependent variables and both subjects (1, …, 10) and sharpness (good, bad) as independent qualitative variables. The "subject" factor was declared as random variable.

3. Results

3.1. Electromyography

Max, $p0.1$, $p0.5$ and $p0.9$ values are shown in Table 1. Analysis shows that the Max, $p0.5$ and $p0.9$ values are, in statistical terms, significantly higher with a "bad cutting" condition blade than with a "good cutting" condition blade, except for the EDC muscle. On the other hand, in all the muscles studied, static level $p0.1$ remains statistically similar in both good and bad cutting conditions.

Max value ratios between the two cutting conditions vary from 1.2 to 2.4 depending on the muscle considered. Thus, the lowest ratios are observed for the EDC (1.2), the UT (1.3) and the flexor digitorum superficialis (1.6) muscles. The highest ratios concern the AD (2.3), the TB (2.3) and the BB (2.4) muscles, respectively.

3.2. Angular deviations

GLM analysis, as described in the methodological section of this paper, shows that only wrist radial deviation differs significantly ($p<0.005$) in statistical terms, according to cutting blade condition. In fact, average radial deviation is 2.5° higher with a "bad cutting" condition blade than with a "good cutting" condition blade (cf. Table 2).

4. Discussion

4.1. Knife sharpness quantification

The present study features a system allowing knife sharpness quantification. This system measures the force exerted on the knife blade, when cutting a 3 cm thick piece of foam rubber with a shear strength close to that of meat

Table 1
Maximum (Max), $p0.1$, $p0.5$ and $p0.9$ values for different muscles studied with respect to blade cutting condition

		Good cutting	Bad cutting	p
FDS (% MVC)	Max (SD)	34.1 (13.4)	54.6 (20.4)	$p<0.0005$
	$p0.1$ (min–max)	2.9 (0.5–15.8)	3.4 (0.6–15.8)	ns
	$p0.5$ (min–max)	14.1 (3.7–32.9)	26.5 (7.9–49.0)	$p<0.001$
	$p0.9$ (min–max)	41.8 (9.8–75.1)	68.0 (24.1–119.8)	$p<0.0005$
EDC (% MVC)	Max. (SD)	36.0 (26.0)	44.4 (33.9)	ns
	$p0.1$ (min–max)	14.0 (4.5–38.8)	16.6 (5.2–42.4)	ns
	$p0.5$ (min–max)	27.9 (7.9–69.8)	32.7 (8.6–89.5)	ns
	$p0.9$ (min–max)	49.9 (14.9–129.6)	57.6 (20.6–162.9)	ns
BB (% MVC)	Max. (SD)	5.7 (3.8)	13.9 (8.1)	$p<0.005$
	$p0.1$ (min–max)	1.0 (0.3–2.4)	1.2 (0.4–2.9)	ns
	$p0.5$ (min–max)	2.8 (0.9–6.5)	6.2 (1.7–14.5)	$p<0.005$
	$p0.9$ (min–max)	8.6 (1.9–19.9)	20.0 (6.6–36.8)	$p<0.005$
TB (% MVC)	Max. (SD)	14.2 (8.4)	32.2 (13.0)	$p<0.0001$
	$p0.1$ (min–max)	1.3 (0.3–3.9)	1.6 (0.3–3.8)	ns
	$p0.5$ (min–max)	4.7 (1.7–12.8)	11.1 (4.3–22.9)	$p<0.0005$
	$p0.9$ (min–max)	16.4 (3.8–48.1)	37.0 (14.1–64.1)	$p<0.0001$
AD (% MVC)	Max. (SD)	26.6 (15.6)	61.3 (28.9)	$p<0.0005$
	$p0.1$ (min–max)	6.3 (2.4–19.4)	8.1 (1.5–20.3)	ns
	$p0.5$ (min–max)	16.2 (8.1–44.6)	23.8 (6.7–54.1)	$p<0.005$
	$p0.9$ (min–max)	36.9 (19.6–84.1)	83.5 (26.2–162.9)	$p<0.005$
UT (% MVC)	Max. (SD)	39.2 (22.3)	50.4 (30.2)	$p<0.05$
	$p0.1$ (min–max)	14.8 (0.8–48.5)	17.7 (0.5–50.9)	ns
	$p0.5$ (min–max)	36.8 (1.8–95.2)	45.5 (4.6–109.7)	$p<0.05$
	$p0.9$ (min–max)	72.7 (5.7–154.2)	110.7 (16.8–362.2)	$p<0.05$

p values indicating the significance level of the difference between "good cutting" and "bad cutting" conditions are included in the right-hand column.

Table 2
Angular deviations (SD) in wrist flexion–extension (ext > 0) and ulnar–radial (radial > 0) and in elbow flexion–extension (flex > 0) according to 2 cutting blade conditions

	Good cutting	Bad cutting	p
Average wrist angle in flexion/extension plane (°)	46.2 (11.8)	45.6 (11.2)	ns
Average wrist angle in ulnar–radial plane (°)	27.6 (6.5)	30.1 (6.1)	$p<0.005$
Average elbow angle in flexion/extension plane (°)	46.9 (10.6)	46.7 (11.6)	ns

p values indicating the significance level of the difference between "good cutting" and "bad cutting" conditions are included in the right-hand column.

(Kopp and Bonnet, 1982). It is difficult to compare force values recorded on this test bench with those reported in the literature because the nature of the sample is different (Bishu et al., 1996; McGorry et al., 2003). Force values reported by Bishu et al. (1996), when carving slices of Bologna round chub steak, are effectively higher than those recorded within the scope of the present study, whilst the opposite is observed for values reported by McGorry et al. (2003), when cutting plastic film.

Cutting force values characterizing good (25–30 N) and bad (75–80 N) sharpness were mainly chosen from two experiments conducted by the laboratory team. The first field-based experiment was conducted on 4 experimented deboners working in the same slaughterhouse. They were asked to work with their knife without honing it, until they considered its sharpness had deteriorated so much that they could no longer work. In this experiment, the cutting force mean value ranged from 26 N, at the beginning, to 41 N, at the end of this period. This corresponds to a cutting force increase of about 60% (Marsot et al., 2004). The second experiment involved testing sharpened or dull knives from French slaughterhouses. In this case, observed cutting force values ranged from 20 N to up 100 N. Many factors can of course influence cutting force: blade steel quality, blade thickness and degree of sharpness. McGorry et al. (2005) have investigated the latter influencing factor.

The results of these two experiments prompted the decision to characterize the good sharpness condition by a 25 N cutting force and the bad sharpness or dull condition

by a 75 N cutting force. This embraces the range of observed cutting force values.

4.2. Muscular activities

For all the muscles considered in this study, sharpness deterioration is accompanied by an increase in electromyographic signal amplitude (Max and APDF values). Postures adopted by the subjects were checked by means of goniometers and the requested cutting action was very similar to those repeated many times every working day by the subjects (assuming highly stereotyped motor control), so this observation can be most likely interpreted as a muscular stress level increase. However, the magnitude of this stress increase varies according to the muscular group considered.

4.2.1. Flexor digitorum superficialis and extensor digitorum communis

Flexor digitorum superficialis and EDC muscular stresses increase by ratios of 1.6 and 1.2, respectively, when the cutting force increases by a ratio of 2.8. This increase is not statistically significant for the EDC muscle.

Analysis of the literature shows that some authors, such as McGorry et al. (2003), have also observed a significant increase in hand gripping force, when knife sharpness deteriorates, whilst others have not noted this (Bishu et al., 1996; Silvin, 2000). Several factors may be involved, when explaining these observation differences:

- level of sharpness deterioration (moderate, major) and its evaluation [quantitative: Bishu et al. (1996) and McGorry et al. (2003, 2005) or subjective: Silvin (2000)],
- hand gripping force measuring method [EMG: Silvin (2000), instrumented knife allowing hand gripping force to be recorded (McGorry et al., 2003) or pressure applied by handle at certain hand locations (Bishu et al., 1996)].

With reference to values suggested by Jonsson (1982), flexor digitorum superficialis and EDC muscular stresses remain high, even with a "good cutting" condition blade ($Fc < 30$ N). This observation, which confirms previous study results (Occhipinti et al., 1993; Christensen and Larsen, 1995; Bao et al., 2001; Juul-Kristensen et al., 2002), is especially significant for the EDC muscle. APDF values concerning this muscle (cf. Table 1) are effectively very much higher than those suggested by Jonsson (1982), even when knife sharpness is good. It is important to emphasize that the EDC can play a very important part in the appearance of MSDs, such as lateral epicondylitis (Fairbank and Corlett, 2002).

Observation of EMG recordings reveals that the main problem concerning EDC activity is the absence of a complete rest phase during the period between two carving sequences. It has already been demonstrated that, in repetitive hand gripping tasks, the finger and wrist extensor muscles remain active during periods between two hand gripping actions (Johanson et al., 1998; Johansson et al., 2004). This phenomenon is reflected by a high $p0.1$ static activation level and increased risk of muscular fatigue appearing (Hägg and Milerad, 1997). This observation may be explained by the fact that these muscles take part not only in extension, but also in wrist stabilizing during hand gripping actions. Therefore, the finger extensor muscle (EDC) would clearly seem to require further research to find acceptable stress conditions within the framework of meat carving tasks.

4.2.2. Biceps brachii and triceps brachii

These muscles are very sensitive to sharpness deterioration within the scope of this experiment. Amplitude ratios of EMG signal Max values or of $p0.9$ peak values between the two blade cutting conditions considered are in fact close to 2.3, whilst the corresponding cutting force ratio is 2.8. The change in these two ratios is closely comparable, without being strictly identical. It should be emphasized the non-linearity of the force-EMG relationships in conjunction with certain muscular mechanical properties (force-length relationship) can explain the difference in these two ratios. APDF values shows that use of knives that cut well enables stresses lower than the reference values suggested by Jonsson (1982) for all the subjects who took part in the experiment (bracketed values in Table 1). This observation was invalid with knives that cut badly.

4.2.3. Anterior deltoid and upper trapezius

Sharpness deterioration, as described in the methodology section of this paper, is accompanied by levels of muscular stress increased by factors of 2.3, for the AD, and 1.3, for the UT, respectively. Due to its function, the AD plays an important part in the movement performed by the subjects and the increased force induced by sharpness deterioration has a very significant effect on this muscle. The function of the UT muscle is more to stabilize the shoulder and, because of this, the increased force in the hand has less effect on this muscle. Nevertheless, the stress difference in these muscles between the two cutting conditions is statistically significant. If we consider the fact that the reference contraction used in the EMG signal standardization procedure represents roughly 10% to 15% of the maximum capacities of the deltoid (Ringelberg, 1985) and trapezius (Mathiassen and Winkel, 1990 in Hägg and Åström, 1997), the APDF mean values recorded in Table 1 are less than the limiting values suggested by Jonsson (1982). However, it would seem (considering the above approximation) that some subjects exceed the trapezius muscle static ($p0.1$) and median ($p0.5$) threshold limiting values. Moreover, the results of this study do not permit us to conclude accurately on the level of acceptability of the stresses in these muscles, when using a knife that cuts well. Additional research should be conducted involving, in particular, a procedure for standardizing EMG signals under maximum conditions.

4.3. Angular deviation

Results show that a reduction in knife sharpness is accompanied by a statistically significant increase in wrist radial deviation, when performing a carving task in a horizontal plane using a knife held with a dagger handgrip. Even if the magnitude of the increase is not very high (2.5°), this significant difference between the conditions of sharpness has been observed for the all subjects. This result should be compared with the observations of Marsot et al. (2004), who reported, using the same cutting measurement system as those of the present study, that varying the blade inclination angle from 0° (knife vertical) to 30° resulted in a cutting force reduction of 33%. Such a result could also explain why operators adopt a more pronounced radial deviation to reduce upper limb forces.

5. Conclusion

The possibility of quantifying knife sharpness, using the system presented above, has allowed the effect of sharpness deterioration on upper limb biomechanical stresses to be demonstrated. Improving knife sharpness enables upper limb muscular stresses to be reduced, justifying clearly the implementation of prevention actions such as operator training in knife sharpening/honing operations. However, the results reveal stresses that remain excessive for the flexor digitorum superficialis muscle and especially for the EDC muscle. This observation reflects the need to pursue research into the stresses sustained by these muscular groups, within the scope of meat carving tasks, to be able to propose other focused prevention routes; for example, knife design (action on knife blade), operating procedure (muscular stress analysis based on different knife handgrips) or work organization (micro-breaks, shift rotation).

Finally, the wrist deviation results could lead to the assumption that increased sharpness also enables the wrist to remain in a more neutral mean position by reducing radial deviation magnitude. However, further investigations should be conducted to ensure the conclusiveness of this observation.

References

Bao, S., Silverstein, B., Cohen, M., 2001. An electromyography study in three high risk poultry processing jobs. International Journal of Industrial Ergonomics 27, 375–385.

Bishu, R.R., Calkins, C., Lei, X., Chin, A., 1996. Effect of knife type and sharpness on cutting forces. Advances in Occupational Ergonomics and Safety I 2, 479–483.

Christensen, H., Larsen, J., 1995. Handgrip strength and forearm activity during meat cutting. In: Anonymous PREMUS BOOK of Abstracts. Montreal, Canada, pp. 72–74.

Claudon, L., 2001. Wrist biomechanical stresses in beef boning. In: Anonymous PREMUS BOOK of Abstracts. Amsterdam, Neederland, p. 24.

CNAMTS, 2004. Statistiques nationales des accidents du travail, des accidents de trajet et des maladies professionnelles-Année 2002. Caisse Nationale d'Assurance Maladie des Travailleurs salariés, Paris, France, 548pp.

Dempsey, P.G., McGorry, R.W., 2004. Investigation of a pork shoulder deboning operation. Journal of Occupational and Environmental Hygiene 1, 167–172.

EN ISO 8442-5, 2002. Matériaux et objets en contact avec les denrées alimentaires. Coutellerie et orfèvrerie de table. Partie 5: spécification du tranchant et essai de conservation du trenchant—AFNOR, Paris, 12pp.

Fairbank, S.M., Corlett, R.J., 2002. The role of extensor digitorum communis muscle in lateral epicondylitis. Journal of Hand Surgery 27B, 405–409.

Hägg, G.M., Åström, A., 1997. Load pattern and pressure pain t hreshold in the upper trapezius muscle and psychosocial factors in medical secretaries with and without shoulder/neck disorders. International Archive of Occupational and Environmental Health 69, 423–432.

Hägg, G., Milerad, E., 1997. Forearm extensor and flexor muscle exertion during simulated handgripping work—an electromyography study. Clinical Biomechanics 12 (21), 39–43.

Johanson, M.E., James, M.A., Skinner, S.R., 1998. Forearm muscle activation during power handgrip and release. Journal of Hand Surgery 23A (5), 938–944.

Johansson, L., Björing, G., Hägg, G.M., 2004. The effect of wrist orthoses on forearm muscle activity. Applied Ergonomics 35, 129–136.

Jonsson, B., 1982. Measurement and evaluation of local muscular strain in the shoulder during constrained work. Journal of Human Ergology 11, 73–88.

Juul-Kristensen, B., Fallentin, N., Hansson, G.-A., Madeleine, P., Andersen, J.H., Ekdahl, C., 2002. Physical workload during manual and mechanical deboning of poultry. International Journal of Industrial Ergonomics 29, 107–115.

Kopp, J., Bonnet, M., 1982. Dureté de la viande et résistance au cisaillement des fibres de collagène. Science des aliments 2 (Special issue 2), 127–132.

Loppinet, M., Aptel, M., 1997. Musculoskeletal disorders in the meat industry. Notes Scientifiques et Techniques no. 162. INRS, Nancy, France, 58pp (in French).

Marklin, R.W., Monroe, J.F., 1998. Quantitative biomechanical analysis of the wrist motion in bone trimming jobs in the meat packing industry. Ergonomics 42 (2), 227–237.

Marsot, J., Claudon, L., Jacqmin, M., 2004. Cutting performance of deboning knives: quantification method and influence study for blade main technical characteristics. Applied Ergonomics, submitted for publication.

Mathiassen, S., Winkel, J., 1990. Electromyography activity in the shoulder-neck region according to arm position and glenohumeral torque. European Journal of Applied Physiology 61, 370–379.

Mathiassen, S., Winkel, J., Hägg, G., 1995. Normalization of EMG amplitude from the upper trapezius muscle in ergonomics studies—a review. Journal of Electromyography and Kinesiology 5 (4), 197–226.

McGorry, R.W., 2001. A system for the measurement of handgrip forces and applied moments during hand tool use. Applied Ergonomics 32, 271–279.

McGorry, R.W., Dowd, P.C., Dempsey, P.G., 2003. Cutting moments and handgrip forces in meat cutting operations and the effect of knife sharpness. Applied Ergonomics 34, 375–382.

McGorry, R.W., Dowd, P.C., Dempsey, P.G., 2005. The effect of blade finish and blade edge angle on forces used in meat cutting operations. Applied Ergonomics 36, 71–77.

Occhipinti, D.M., Colombini, M., Bulgheroni, M., Grieco, A., 1993. An evaluation of commercially available plastic handled knife handles. In: Marras, W.S., Karwowski, W., Smith, J.L., Pacholski, L. (Eds.), The Ergonomics of Manual Work. Taylor & Francis, London, pp. 331–334.

Ringelberg, J.A., 1985. EMG and force production of some human shoulder muscles during isometric abduction. Journal of Biomechanics 18 (12), 939–947.

Silvin, S., 2000. Biomechanical Stresses of the Operators in the Carving Plants. Henri Poincaré University, Medical Faculty, Nancy, France (in French).

Szabo, R.L., Radwin, R.G., Henderson, C.J., 2001. The influence of knife dullness on poultry processing operator exertions and the effectiveness of periodic knife steeling. American Industry and Hygiene Association Journal 62, 428–433.

Zipp, P., 1982. Recommendations for the standardization of lead positions in surface electromyography. European Journal of Applied Physiology 50, 41–54.